Research Accomplishments 1977 Through 1980

ENGINEERING RESEARCH AND DEVELOPMENT BUREAU
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
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RESEARCH ACCOMPLISHMENTS: 1977 THROUGH 1980

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New York State Department of Transportation
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EXECUTIVE SUMMARY

The Engineering Research and Development Bureau conducts a formalized research program for the New York State Department of Transportation. The work supports the Department's goal of providing adequate, safe, efficient transportation facilities and services at a reasonable cost. To accomplish this, the Bureau conducts two general programs -- Technical Assistance and Experimentation. Under the Technical Assistance Program, information exchange, consultation, and implementation services are provided Department program managers. The Experimentation Program focuses the Bureau's resources, through specific research projects, on the solution of high priority engineering problems. Individual projects are requested or endorsed by Department program managers.

This report reviews accomplishments and activities that were the direct result of research or were supported by research since April 1, 1977. That period was selected because the size of the program and staff have been more or less stable since a reduction in forces in 1976. Many of the items have resulted in less expensive and/or more durable materials, improved test methods, more efficient construction practices, more accurate design procedures, improved maintenance techniques, and increased highway safety. The accomplishments and activities are listed under the following categories: Construction Materials and Methods, Barriers and Roadside Appurtenances, Driver Information and Guidance, Structural Design, Pavement Design, Maintenance, and Other.

It is difficult to place a dollar value on all of the accomplishments and activities resulting from or influenced by the conduct of a research and development program. However, using reasonable assumptions, it is possible to quantify many of the benefits. A review of the items resulted in identifying annual recurring savings for about one-third of them. This is not to say that there are no benefits from the remaining two-thirds, but only that their benefits defy reasonable quantification with the information available. Therefore, it is impossible to calculate an exact benefit/cost ratio to determine the return on the engineering research investment. However, a conservative ratio was obtained from the total estimated annual recurring savings that could be identified and the average annual research expenditure. The result indicates that recurring benefits of over $10 each year are being realized for every dollar spent. This is conservative, because benefits from the other items would increase this return. Thus, it is apparent that the State has received a very favorable return on its engineering research investment.

OUTSTANDING ACCOMPLISHMENTS

Many benefits resulting from Engineering Research over the last 4 years are listed in this report. While all are important, some of the more significant items are as follows:

- Demonstrated that traffic need not be routed from bridges during placement and curing of restoration concrete, thus avoiding cost of crossover pavement and temporary detours on possibly 50 percent of deck restoration and replacement projects. Possible savings of $3 million per year.

- Recommended use of a single vibratory roller instead of usual three-roller train for bituminous concrete pavement, and developed a generic method of accepting vibratory rollers (RR 64, RD #5, RD #8) - $260,000/yr.

- Determined the annual rate at which metal is worn or rusted away in galvanized steel culverts, thus allowing precise, efficient designs tailored to specific service-life needs (RD #7) - $150,000/yr.

- Demonstrated the acceptability of thick-lift wearing course construction for late-season bituminous paving (RR 41, RD #1, RD #8) - $95,000/yr.

- Measured the annual corrosion rate of controlled oxidizing steel guiderail and posts. Rails were found to be in good shape, but recommended that posts be coated below-grade to prevent rapid deterioration and unsafe barrier systems - $10,000/yr.

- Recommended full-width paving of all mainline asphalt pavements, where traffic permits, to eliminate any longitudinal joint between lanes. Developed guidelines for coping with longitudinal joints in asphalt pavements where full-width paving is not feasible (SR 54, RD #1).

- Collected data to show that compliance with requirements for concrete cover depth over steel reinforcement was poor, and suggested alternative designs (RR 67, RR 69, RR 75, RR 78, RD #7, RD #11).

- Tested and refined box-beam and thrie-beam upgradings for existing substandard steel bridge rail to meet current safety standards at much lower cost than new railing (RR 85, RR 92, RD #14) - $550,000/yr.

- Developed a range of construction zone barriers to fit the needs of specific work sites at the lowest cost, while still providing adequate crash protection. Designs include innovative use of steel and timber, plus shorter sections (8 ft long) of concrete barrier that can easily be handled with maintenance equipment (RR 82, RD #12) - $700,000/yr.

- Developed sign supports for both small and large signs that provide improved safety to small vehicle occupants, but are lower in cost and easier to maintain than many commercially available supports (RR 81, RR 94, RD #12) - $2,434,000/yr.

- Provided technical assistance to the Attorney General's office concerning several negligence suits against the Department arising from traffic barrier accidents.

- Thermoplastic and epoxy pavement markings placed on construction contracts are providing greatly improved durability and lower life-cycle costs than paint stripes installed by maintenance forces (RR 87, RD #16) - $400,000/yr.

- Identified and implemented traffic paint formulations now used by Highway Maintenance, which are lower in cost and less expensive to install than those previously used (RR 48, RD #1) - $2 million/yr.

- Developed specification for lower-cost reflective glass beads in thermoplastic pavement markings which still provide adequate visibility (RR 36) - $54,000/yr.

- Demonstrated that snowplowable raised pavement markers provide a high level of wet-night delineation at high-accident locations around the state. Design improvements originating from research efforts have led to lower construction and maintenance costs for these markers (RR 84, RD #13) - $144,000/yr.

- Demonstrated that conventional bridge deck reinforcement is excessive, and that the quantity of steel reinforcement can be reduced (RR 89, RD #15) - 1 million/yr.

- Conducted field studies that permitted estimates of minimum design life for concrete bridge decks with different amounts of protective concrete cover over reinforcing bars (RR 75, RR 93, RD #11).

- Recommended sawing and sealing of bituminous concrete overlays to control reflection cracking (RR 80, RD #12) - $550,000/yr.

- Demonstrated the feasibility of using thinner portland cement concrete pavement for low-volume highways.

- Evaluated various pavement patching materials and methods (RR 74, RD #9) - $603,000.

- Determined the effectiveness of ground geared salt spreaders with automatic controls (SR 43) - $960,000.

CONTENTS

I. INTRODUCTION

The Engineering Research and Development Bureau was established to conduct a formalized research program for the New York State Department of Transportation. The staff obtains problems from operating units and proceeds to plan and conduct specific studies. In addition, they serve as resource people by obtaining information, consulting, and promoting implementation of our own research results as well as those of other agencies. Since the Bureau's primary function is research, its personnel have no other responsibilities. Thus, pressures of the state's highway design, construction, maintenance, and operation activities do not force postponement of vital research investigations -- an arrangement that has proved to be a key factor in the success of this program.

The New York State Department of Transportation is charged with implementing state transportation policy "that adequate, safe, and efficient transportation facilities and services at reasonable cost to the people are essential to the economic growth of the state and the well-being of its people."* The mission of the Engineering Research and Development Bureau is to support this goal through research and development in the traditional disciplines of engineering and engineering science. The Bureau does this through five major functions:

1. Identifying and defining subjects that are researchable -- that is, suitable and manageable for study.

   Many problems are submitted to the research group for solution. It is vital that these ideas be carefully screened to determine which are unsuitable for research, which can be solved with technical knowledge currently available, and which require further investigation to obtain a solution. Considerable effort is involved in defining a worthwhile investigation -- there are no shortcuts in the path from an idea for research to a project statement. Engineers knowledgeable in research procedures must consult with those in operating units who have firsthand knowledge concerning the problem. The entire success of the research effort hinges on their ability to identify and define the research subject precisely.

2. Formulating engineering research programs, based on the most favorable benefit/cost ratios.

   There are always many more suitable research projects than funds and personnel to carry them out. Therefore, each project must be analyzed in order to determine a best estimate of benefits in relation to costs.

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*Chapter 717, Laws of 1967, Section 10.

3. Conducting necessary experimental work in-house, or administering contracts for its progress elsewhere.

   Research may be progressed either by staff or by contract. This Bureau's policy has been to staff for engineering research projects dealing with applied problems in transportation technology. Research contracts have been reserved for basic research requiring a technical competence outside that normally encountered in civil engineering.

4. Disseminating research findings and actively engaging in their implementation throughout the Department.

   Dissemination of research findings is essential for avoidance of duplication of expenditure and effort, and so that the entire transportation industry can be made aware of the latest available technology. Within the Department of Transportation, however, mere awareness of research results would have little effect on policies and practices without a vigorous program of implementation. Experience has shown that a research report by itself is not sufficient to bring about change. Research results must be "sold" to those responsible for instituting changes. Additional explanations are usually required, questions must be answered, and the person responsible for implementation of the improved specification, standard, or method expects assistance in getting the word to those who must ultimately put the idea into practice.

5. Maintaining technical competence in all aspects of engineering that pertain to Department activities, including keeping in touch with new engineering research developments throughout the world.

   A primary responsibility of the Engineering Research Bureau is keeping abreast of the latest technical developments achieved through the efforts of other researchers. This is accomplished by formal exchange of research publications, continuing review of the technical literature, attendance at professional meetings, and membership on committees of various technical organizations.

To perform these five major functions, the Bureau conducts two general programs -- Technical Assistance and Experimentation. Under the Technical Assistance program, liaison is formally established between Bureau engineers and representatives designated by each Department program manager. When engineering problems or questions arise, liaison representatives can contact research engineers who may have the desired information. If not, research engineers contact the Highway Research Information Service (HRIS) at the Transportation Research Board in Washington. In 1980, Bureau engineers requested 46 searches for employees of the Offices of Engineering and Operations, resulting in circulation of 2399 abstracts of completed reports and descriptions of studies in progress. Research engineers also contact knowledgeable Department people or other engineers in the research community in general. Upon request, specific investigation or consultation services of limited scope and duration which draw on the Bureau's specialized talents and capabilities are provided. Under the Experimentation Program, the

resources of the Bureau are applied to solve those engineering problems of highest priority, within the competency of the Bureau staff and for which sufficient other resources are available, and to contract for urgently needed research in cases where sufficient resources are not readily available in the Department.

The Bureau has 70 allocated positions, divided among engineers, technicians, and support personnel. Studies are progressed by six research teams, whose objectives are as follows:

1. Appurtenances and Operations

   Objective: Develop and evaluate transportation appurtenances such as guiderails, sign supports, signs, delineators, and other roadside "furniture," as well as conduct engineering research in traffic operations.

2. Geotechnics

   Objective: Develop and evaluate design criteria, construction procedures, and maintenance practices related to soil structures and foundations, and drainage facilities.

3. Materials

   Objective: Develop data and other information necessary to prepare new specifications and improve existing specifications for construction and maintenance materials; and support design, construction, and maintenance practices that promote effective, economical use of such materials for optimum performance.

4. Pavements

   Objective: Develop data necessary to support design, construction, and maintenance practices that will decrease initial and maintenance costs, increase service, optimize performance, and extend the life of pavements.

5. Structures

   Objective: Develop and verify new structural design techniques and refine existing methods through theoretical analysis and physical testing, to decrease initial and maintenance cost and optimize performance.

6. Special Projects

   Objective: Provide investigational services to the Department that are of a unique or unusual nature and require design and development of special testing equipment, and to progress a variety of research in response to experimental needs of the Department not met by other Bureau programs.

II. BENEFITS OF DOING RESEARCH

What savings can be attributed to research is a question that is asked perennially. To answer such an inquiry, it is helpful to outline the different forms of research payoffs in highway engineering. The least common research payoff is the invention of an entirely new product or method. While one occasionally emerges, most efforts to revolutionize the transportation industry fall short of expectations. Historically, it has been demonstrated that most productive research has involved a steady improvement of conditions through a process of evolution. This work is often concerned with the innovative adoption of technology from other disciplines (or industries), or modifying currently used materials or methods. In this context, the most common research payoff provides information to select the optimum material or method from among several alternatives. However, in considering these alternatives, the restraints of Department policies, goals, and objectives must be recognized.

Listed in these next few pages are accomplishments and activities that were the direct result of research or were supported by research since April 1, 1977. The period covered was selected because the size of the program and staff have been more or less stable since a reduction in forces in 1976. Also for this period, the Bureau has been publishing the Quarterly R&D Digest, which provides added insight into the work completed and initiated. Copies of all 16 Digests are included in the Appendix.

Individual items on the following list were either implemented or are in the process of being implemented. Items in the latter category (marked with an asterisk) have been included because details of the implementation have been worked out with appropriate program managers in the Department's operating units and most of the Bureau's work has been completed. All that remains is the issuance of standard sheets, an Engineering Instruction, a specification, changes in various Design Manuals, or some similar document.

For some of the items it was possible to quantify annual dollar savings resulting from the action indicated, but for others it was not. Quantifiable recurring annual savings have been listed after the appropriate items. In addition to the appended Research Digests (RD), more detailed information is available on many of the accomplishments in Research Reports (RR) and Special Reports (SR), available on request from the Bureau.

Accomplishments and activities are categorized under the following headings: Construction Materials and Methods, Barriers and Roadside Appurtenances, Driver Information and Guidance, Structural Design, Pavement Design, Maintenance, and Other.

A. Construction Materials and Methods

1. Overview

Research on construction materials and practices includes developing data and other information to support materials specifications as well as design, construction, and maintenance practices that promote effective use of these materials.

2. Accomplishments and Activities

- Developed acceptance sampling plans for neoprene joint sealers and structural paint (RR 53, RR 65, RD #1, RD #6) - $87,000/yr.
- Recommended use of a single vibratory roller instead of usual three-roller train for bituminous concrete pavement, and developed a generic method of accepting vibratory rollers (RR 64, RD #5, RD #8) - $260,000/yr.
- Demonstrated the acceptability of thick-lift wearing course construction for late-season bituminous paving (RR 41, RD #1, RD #8) - $95,000/yr.
- Improved joint sealers for concrete pavement are extending pavement life and reducing the necessity of frequent and expensive sealer replacement (RR 76, RD #10, RD #11) - $775,000/yr.
- Determined the annual rate at which metal is worn or rusted away in galvanized steel culverts, thus allowing precise, efficient designs tailored to specific service-life needs (RD #7) - $150,000/yr.
- Demonstrated that traffic need not be routed from bridges during placement and curing of restoration concrete, thus avoiding cost of crossover pavement and temporary detours on possibly 50 percent of deck restoration and replacement projects. Possible savings of $3 million per year.
- Developed and validated less costly and safer lab procedures for capping concrete test cylinders with neoprene rather than with hot-poured molded sulfur mortar (RR 46, RD #1) - $8,000/yr.
- Measured the annual corrosion rate of controlled oxidizing steel guiderail and posts. Rails were found to be in good shape, but recommended that posts be coated below-grade to prevent rapid deterioration and unsafe barrier systems - $10,000/yr.*
- Identified the major factors affecting the repeatability of the magnesium sulfate soundness tests for gravels. Allows more precise determination of quality and therefore reduces chance of premature failure of pavement bases and subbases - $25,000/yr.*

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*Changes in standards or practice are being processed.

- Demonstrated the superior field performance of waterproofing membranes other than the standard bituminous-epoxy system then used on bridge decks. The old standard was discontinued (RR 52, RD #1).

- Determined from field studies that reinforcing bar corrosion in restored bridge decks returns rapidly to pre-restoration levels unless chloride-contaminated concrete is removed. This provided "real world" evidence in support of that obtained previously from model studies only, reinforced Federal restoration policy, and confirmed the validity of current Department restoration practice (RR 52).

- Increased production and improved ride quality of bituminous pavements by encouraging the use of heated screed extensions, and requiring automatic grade-slope controls on all mainline asphalt pavers.

- Demonstrated the feasibility of recycling bituminous concrete material.

- Determined from long-term field studies that storing asphalt concrete at elevated temperatures for prolonged periods, a producer convenience that accommodates short-term imbalances between demand and production and reduces cost, results in no harmful effect on the performance of asphalt pavement (RR 54, SR 65, RD #2, RD #9).

- Developed procedures for accelerating the curing of concrete cylinders so that 28-day strengths can be accurately predicted after 2 days. Adoption has resulted in early detection of unacceptable concrete and has permitted early opening of bridges (RR 55, RD #2, RD #3).

- Made temperature measurements that were the basis for elimination of a requirement for longitudinal joint heaters on hot-mix pavers.

- Recommended full-width paving of all mainline asphalt pavements, where traffic permits, to eliminate any longitudinal joint between lanes. Developed guidelines for coping with longitudinal joints in asphalt pavements where full-width paving is not feasible (SR 54, RD #1).

- Identified limestone and dolomite rocks in New York that have the potential to react chemically in concrete with high-alkali cements, causing cracking and sometimes structural failure (SR 57, RD #3).

- Collected data to show that compliance with requirements for concrete cover depth over steel reinforcement was poor, and suggested alternative designs (RR 67, RR 69, RR 75, RR 78, RD #7, RD #11).

- Determined that aggregates originally proposed for I 87 resurfacing mixes should not be used even with anti-stripping agents as originally planned (SR 67, RD #12)

Estimated Annual Recurring Savings = $4,410,000

B. Barriers and Roadside Appurtenances

1. Overview

Major improvements have been achieved in the traffic barriers and sign supports used by the Department through full-scale tests at the Scotia Test Center. These improvements have produced construction and maintenance cost savings as well as substantial safety benefits.

2. Accomplishments and Activities

- Tested and refined box-beam and thrie-beam upgradings for existing substandard steel bridge rail to meet current safety standards at much lower cost than new railing (RR 85, RR 92, RD #14) - $550,000/yr.

- Developed a range of construction zone barriers to fit the needs of specific work sites at the lowest cost, while still providing adequate crash protection. Designs include innovative use of steel and timber, plus shorter sections (8 ft long) of concrete barrier that can easily be handled with maintenance equipment (RR 82, RD #12) - $700,000/yr.

- Developed sign supports for both small and large signs that provide improved safety to small vehicle occupants, but are lower in cost and easier to maintain than many commercially available supports (RR 81, RR 94, RD #12) - $2,434,000/yr.

- Demonstrated the crash-worthiness and low maintenance requirements of a median barrier end terminal proposed for high-volume arterial highways. This design is much less costly to build and maintain than the alternates used elsewhere (report pending) - $115,000/yr.

- Established design guidelines that will permit safe use of traffic barriers in sharply curved installations (RR 83, RD #12) - $200,000/yr.*

- Obtained data on the impact performance and maintenance costs of newly implemented safety hardware, confirming major safety improvements compared to older designs, as well as lower maintenance costs in some areas (RR 51, RR 57, RD #2, RD #3, RD #6).

- Designed and evaluated the Vickerman Hill gravel bed truck arrestor in Herkimer County (RR 68, RD #7).

- Prepared an analysis procedure to permit the Office of Legal Affairs and the Traffic and Safety Division to more easily summarize and analyze tort liability claims against the Department arising from highway accidents.

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*Changes in standards or practice are being processed.

- Conducted training sessions on construction zone barriers at the 1980 Resident Engineers' meeting and the 1980 Construction Engineers' meeting.

- Provided NYSDOT input to Federal Highway Administration (FHWA) research activities through participation in annual FCP review meetings.

- Provided technical input in response to a large number of requests for assistance, ranging from design problems on individual projects to the development of standards and specifications for Department-wide use.

- Provided technical assistance to the Attorney General's office concerning several negligence suits against the Department arising from traffic barrier accidents.

- Participated on the Highway Safety Review Team, which jointly with FHWA provides an annual evaluation of Department highway safety programs.

- Provided technical input on numerous occasions to Department representatives and program managers to assist in formulating Department responses to proposed FHWA, AASHTO, NTSB, and NHTSA standards, policies, and regulations.

- Made recommendations to the Office of Legal Affairs on proposed litigation concerning the location of utility poles on Department right-of-way.

Estimated Annual Recurring Savings = $3,999,000

C. Driver Information and Guidance

1. Overview

Pavement markings and highway signing are vital to the safe, orderly flow of traffic on modern highways, especially under adverse conditions such as nighttime, rainfall, and fog. Improved materials and techniques have produced substantial savings in construction and maintenance costs, in addition to major safety improvements.

2. Accomplishments and Activities

- Eliminated ineffective asphalt surface treatments used to provide shoulder delineation (RR 71, RD #7) - $312,000/yr.

- Thermoplastic and epoxy pavement markings placed on construction contracts are providing greatly improved durability and lower life-cycle costs than paint stripes installed by maintenance forces (RR 87, RD #16) - $400,000/yr.

- Identified and implemented traffic paint formulations now used by Highway Maintenance, which are lower in cost and less expensive to install than those previously used (RR 48, RD #1) - $2 million/yr.

- Developed specification for lower-cost reflective glass beads in thermoplastic pavement markings which still provide adequate visibility (RR 36) - $54,000/yr.

- Demonstrated that snowplowable raised pavement markers provide a high level of wet-night delineation at high-accident locations around the state. Design improvements originating from research efforts have led to lower construction and maintenance costs for these markers (RR 84, RD #13) - $144,000/yr.

- Developed guidelines for the use of flashing arrow boards in highway work zones, resulting in improved safety and reduced costs for providing traffic protection (RR 73, RD #9) - $1,115,000/yr.

- Showed that transverse grooves installed at slippery intersections on Rte 7 in Latham reduced accidents and were less expensive than overlaying the worn concrete with high-friction asphalt (SR 53, RD #1) - $108,000/yr.

- Provided engineering data needed to ensure the proper design and maintenance of large highway guide signs around the state. Data was obtained from a statewide survey of sign legibility (RR 50, RD #2).

- Prepared an overview of current pavement marking technology and distributed it statewide, both to the Department and to local agencies, through the Quarterly R&D Digest (RD #16).

- Filled a large number of requests for information on signing and pavement markings, both within the Department and from other agencies.

- Provided engineering responses to program managers on several occasions, ranging from individual design problems to the review of proposed Department-wide standards and specifications.

- Completed a technical review of the revised NYS Manual of Uniform Traffic Control Devices (MUTCD) to ensure that it reflects recently completed research on driver guidance.

- Confirmed the effectiveness of yellow-on-brown motorist information signs to enhance the scenic beauty of highways in the Adirondack Park, thus permitting their eligibility for Federal funding (RR 56, RD #3).

Estimated Annual Recurring Savings = $4,133,000

D. Structural Design

1. Overview

Research in structures design involves testing and evaluation of new design concepts proposed by Department engineers. This is done because the complexity of many structural elements makes mathematical analysis infeasible, and simplifying assumptions based on empirical findings are necessary. Thus, field measurements on actual bridges or laboratory testing of scale models becomes necessary.

2. Accomplishments and Activities

- Showed that ordinary concrete was suitable for replacement of bridge deck wearing surfaces (RR 75, RD #11) - $300,000/yr.
- Demonstrated that conventional bridge deck reinforcement is excessive, and that the quantity of steel reinforcement can be reduced (RR 89, RD #15) - 1 million/yr.*
- Developed data from field experimentation that will permit use of long-span aluminum culverts on an equal basis with steel (RR 90).
- Developed a simplified design procedure for estimating in-service stresses in horizontally curved steel bridge girders (RR 60, RR 61, RD #4).
- Demonstrated that field behavior of steel box-girder bridges was consistent with design assumptions (SR 59, RD #6).
- Conducted field studies that permitted estimates of minimum design life for concrete bridge decks with different amounts of protective concrete concrete cover over reinforcing bars (RR 75, RR 93, RD #11).
- Collected data to show that a proposed revision to the design estimation of prestressed concrete longitudinal movement should not be implemented (RR 66, RD #6).
- Performed laboratory testing to explain the distribution of longitudinal forces to bridge bearings (SR 58, RD #6).
- Used field test results to prove that the load capacity of concrete bridges is not directly related to the observed condition of the structure (RR 79, RD #11).
- Collected service performance data on jointless bridges which may lead to revision in design standards.
- Recommended wind-load design factors for noise barriers.

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*Changes in standards or practice are being processed.

- Constructed and tested a scale model of a revised reinforcing design for concrete bridge parapets using less steel. Model testing can be performed at lesser cost than tests on full-size component.

- Obtained in-service measurements of the behavior of the deteriorated bridge in Dresden (Rte 14) which permitted the structure to remain open to traffic during repair.

- Monitored the forces in the Massena bridge (Rte 54) during the passage of a 650,000-lb transformer to assure no damage to the structure.

- Reviewed design standards for bolted splices in bridge girders and recommended revisions.

Estimated Annual Recurring Savings = $1,300,000

E. Pavement Design

1. Overview

The research involved with this topic is intended to provide a balance between initial cost and service. A well-designed pavement is built as economically as possible by using adequate materials (properly handled and treated), and the soundness of the design is judged by demand maintenance required, life to first repaving, and thickness of overlay required. How these features relate to each other determines whether a particular pavement design is a sound investment.

2. Accomplishments and Activities

- Changed portland cement concrete (PCC) pavement design from 60-ft reinforced slabs to 20-ft unreinforced slabs (RD #10) - $490,000/yr.
- Recommended sawing and sealing of bituminous concrete overlays to control reflection cracking (RR 80, RD #12) - $550,000/yr.
- Demonstrated the effectiveness of "open-graded friction courses" in pavement resurfacing. This new material enhances safety through greater friction resistance over standard mixes, and reduces cost where it can be used to remedy a high accident site in lieu of changing geometrics (RR 58, RD #3).
- Determined from field studies that 1968 changes in specification for limestone coarse aggregate used in bituminous concrete have reduced by about two-thirds the occurrence of unacceptably low values of friction resistance. Recommendations for further improvements have been made and are under consideration (RR 77, RD #11).
- Prepared state-of-the-art report on concrete overlays, currently being used in considering such overlays (SR 62).
- Demonstrated the feasibility of using thinner portland cement concrete pavement for low-volume highways.
- Observations of many overlays supported the decision not to increase overlay thickness on rigid pavements for the purpose of reducing reflection cracking.
- Recommended the breaking up of badly deteriorated concrete pavement before overlaying.
- Determined that fabrics placed over transverse joints before overlaying rigid pavements did not reduce reflection cracks in the overlay, and therefore discouraged their use.

- Evaluated effectiveness of current and proposed methods of texturing concrete pavement, since surface texture is the principal means of imparting friction resistance. Recommended changes in the design of the texturing tools and an increase in texture depth requirements on new construction. Developed sampling plans and instructions for using sand-patch test to measure texture. Recommendations are under consideration (RR 62, RR 70, RR 86, RD #5, RD #7, RD #14).

- Supplied profilograph measurements that supported the Department's response to the Federal Highway Administration, informing them that a roughness specification for newly-constructed asphalt pavement was not necessary.

- Determined feasibility and relative efficiency of milling and planing asphalt pavements, which is more cost-effective than raising curbs, manholes, and drop inlets (RR 44, RD #1).

- Recommended the use of a one-piece load-transfer device to replace the two-component device in PCC pavement and thus reduce joint deterioration.

Estimated Annual Recurring Savings = $1,040,000

F. Maintenance

1. Overview

Highway Maintenance research work falls into two categories -- improving maintenance activity methods and improving systems management techniques. The former is needed to improve the cost effectiveness of these activities, and the latter is needed for developing sound systemwide strategies for preserving the highway network. The systems management research is all ongoing or planned for the near future.

2. Accomplishments and Activities

- Evaluated various pavement patching materials and methods (RR 74, RD #9) - $603,000.
- Determined the effectiveness of ground geared salt spreaders with automatic controls (SR 43) - $960,000.
- Analyzed structure inspection data to assess current structural deterioration and its implications (SR 70, RD #14).
- Investigated various materials and methods to reseal transverse joints in PCC pavements, and recommended timely resealing to extend pavement's service life by retarding joint faulting and reducing blow-ups (RR 49, RD #1).

Estimated Annual Recurring Savings = $1,563,000

G. Other

1. Overview

Listed under this category are items that do not fit into the other six categories. Two of the items, the Experimental Features Program and the Demonstration Projects, result in the state receiving additional funding from FHWA. A third ongoing activity involves the dissemination of information made available through FHWA.

2. Accomplishments and Activities

- Coordinating the Experimental Features Program for the Department, which obtains federal funding for non-standard construction items -$100,000/yr.

- Prepared statements on the historic significance of 12 bridges, 10 of which were declared not eligible for National Register listing, thus eliminating at least a one-year delay on those ten projects. It is estimated that timely construction resulted in savings of $3 million over the last four years - $750,000/yr.

- Coordinating FHWA's Demonstration Projects Program for the state. This program provides technical assistance and funding from FHWA to demonstrate newly developed, proven technology to state and local governments. As an example, the most recent Demonstration Project concerning the use of sulfur to extend asphalt resulted in $42,000 from FHWA.

- Coordinating the Technology Transfer Program for the Department that disseminates research results, technology-sharing reports, and implementation packages to Department program managers, other state agencies, and local governments.

Estimated Annual Recurring Savings = $850,000

III. RETURN ON THE RESEARCH INVESTMENT

Although it is difficult to place a dollar value on all of the accomplishments and activities resulting from the conduct of a research and development program, it is possible to do so on some. This is not to say that the others are not beneficial, but only that they defy reasonable quantification with the information available. Of the accomplishments and activities listed in the previous chapter, annual savings were estimated for about one-third. To obtain a gross minimum estimate of the benefit-cost ratio for research functions over the period since April 1, 1977, a comparison can be made between the estimated annual recurring savings for those items where it was possible to reduce benefits to dollars and the average annual research expenditures.

Estimated Annual Recurring Savings

Construction Materials and Methods	$ 4,410,000
Barriers and Roadside Appurtenances	3,999,000
Driver Information and Guidance	4,133,000
Structural Design	1,300,000
Pavement Design	1,040,000
Maintenance	1,563,000
Other	850,000
Total	$17,295,000

Annual Research Expenditures*

1977-78	$1,497,000
1978-79	$1,567,000
1979-80	$1,580,000
1980-81	$1,727,000

Average Annual Expenditure = $1,593,000

*Obtained from the Department's Integrated Accounting System and salaries include the Department's share of fringe benefits.

$$\frac{\text{Total Annual Recurring Savings}}{\text{Average Annual Expenditure}} = \frac{\$17,295,000}{\$\ 1,593,000} = 10.8$$

Admittedly, this is a conservative figure because about two-thirds of the projects are not included. Benefits from these will increase this ratio. From this analysis, it is apparent that the Department has received a very favorable return on its research investment.

IV. ANTICIPATED SAVINGS FROM CURRENT RESEARCH

A. Overview

In addition to the work that has already produced results, studies are now underway from which implementable results and savings can be anticipated. Although some work is needed before implementation, the following list of items is included to indicate some of the benefits the Department will realize in the near future. Where possible, potential annual savings have been estimated. These were not included in the benefit/cost ratio in the previous chapter.

B. Potential Savings from Research Underway

- Improved design and construction methods are under investigation to ensure that cable guiderail remains properly tensioned year-round without the necessity of frequent adjustments by maintenance forces - $663,000/yr.

- Alternate traffic barrier designs based on triple-corrugated steel beam (thrie-beam) have been recommended as an economical alternate to the now-standard box-beam for certain installations (RR 85).

- Optimized maintenance procedures are being developed for reflective traffic signs that will minimize maintenance expenditures and prolong sign life - $240,000/yr.

- Comparative tests of several new pavement marking materials are being performed to determine which will provide long-term wet-night delineation at the same or less annual cost than the paints now used by Highway Maintenance - $6,000,000/yr.

- The potential for further reduction of steel reinforcement in portland cement concrete bridge decks is under investigation and could save an additional $1 million/yr.

- Results from the evaluation of the durability and cost-effectiveness of various snowplow blades could save $100,000/yr.

- Research personnel are assisting in implementing a FHWA Demonstration Project for utilizing solar energy in residency facilities - $100,000/yr.

- Reviewing bridge condition reports and performing a general economic analysis, using various preventive maintenance strategies, indicates that the long-term effect of currently available funds can be improved - $225,000/yr.

- Analyzing, in detail, the effectiveness of bridge maintenance strategies and tasks being performed, and optimizing the funding level for preventive maintenance - $7,500,000/yr.

- Studying the accomplishment rates of snow-and-ice control activities and the level of need for these activities to keep highways operational during storms.

- Developing an acceptance sampling plan for thermoplastic materials - $200,000/yr.

- Studying new materials and installation methods to extend the life expectancy of inductive loop detectors for vehicles approaching traffic signals - $100,000/yr.

- Evaluating seven different metallic and non-metallic coating systems to prevent deterioration of corrugated steel pipe. Results will allow the use of the best-suited system for each culvert installation.

- Examining the concept of reducing the depth of bridge abutment footings by 2 ft. If feasible, savings of up to $150,000 annually will be realized.

- Monitoring developments in the field of plastic pipe for cross-culverts. Their future use could result in substantial annual savings in first-instance costs, as well as annual maintenance costs.

- Monitoring the performance of "powder-coated" steel bridge rail, guiderail, and sign posts as a potential replacement for conventional galvanized steel.

- Initiating an inventory and computer file of potentially historic bridges to provide a basis for a rational assessment of importance from which a preservation recommendation can be made. If this results in preventing delays to only four bridge replacement projects per year, the annual savings could be $1,200,000.

APPENDIX

THE FIRST SIXTEEN ISSUES OF THE QUARTERLY R&D DIGEST

(Copies of the first 16 issues of the Digest have been omitted from this printing of Research Accomplishments: 1977 Through 1980, but are available upon request for interested readers by calling (518) 457-7477, or writing the Engineering Research and Development Bureau, New York State Department of Transportation, State Campus, Albany, New York 12232.)